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PROFESSIONAL PAPERS OF THE CORPS OF ENGINEERS, U. S. ARMY.
No. 21. Dup.

REPORT

ON

THE FABRICATION OF IRON

FOR

DEFENSIVE PURPOSES,

AND

ITS USES IN MODERN FORTIFICATIONS,

ESPECIALLY IN

WORKS OF COAST DEFENSE.

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1872.

New York, *April* 2, 1872.

General: I herewith enclose a report of such information as I was able to collect, "concerning the use of iron in sea-coast defenses," during my stay in Europe, under authority from the Honorable Secretary of War, in conformity to the recommendation of your letter of August 2, 1871.

The brief period I spent abroad was almost wholly and necessarily devoted to the duties in which I was particularly engaged, and I could undertake no systematic work in another field.

My previously acquired knowledge, however, enabled me to judge of the actual state of the question in England almost as accurately as if I had again visited every point.

In making this report, I have thought it desirable to include in it so much of the information that has, since the date of the Report of the Commission, become in any way accessible, as would render it a tolerably full supplement to that document, so far, at least, as English construction is concerned.

Very respectfully, your most obedient,

J. G. BARNARD,

Colonel of Engineers and Brevet Major-General.

Brigadier General A. A. Humphreys,

Chief of Engineers U. S. A., Washington, D. C.

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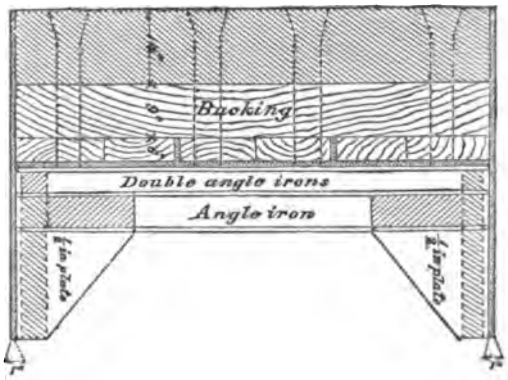
NEW YORK, *April* 1, 1872.

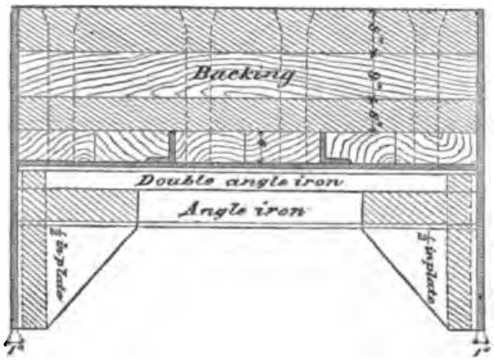
GENERAL: I have elsewhere stated that, owing to limited time and paramount duties of another character, I was unable to devote much time to a renewed investigation of "the use of iron in sea-coast defenses."

There has doubtless been progress at many points in *construction*, but new developments of importance are not believed to have been made in Europe during the interval which has elapsed since the date of the "Report on the Fabrication of Iron for Defensive Purposes," (Professional Papers of the Corps of Engineers, No. 21.)

The most important experiments in England were those which took place at Shoeburyness on the 4th of May and the 5th of July, (1871.) I took occasion to examine the target-structures, at a subsequent experimental firing made for the benefit, and in honor of the foreign officers who attended the Aldershot manœuvres.

The object of the experiments of the first-named date are indicated as follows by the "Standard:"*





"Very thick armour-plates, of twelve inches in thickness, have been shot at on some former occasions, and have been disrupted in a few rounds by heavy guns of less power than the 600-pounder brought to bear on the present occasion against the representative target of the turret of the Devastation, armoured with fourteen inches of solid iron. One source of the difference of the results yesterday, which were most honourable alike to the guns and the targets—victorious, however, on the side of the latter—will have been in the superiority of the present armour-plates, rolled in larger and more powerful mills than those formerly produced; but the fact that the thick plates were now for the first time properly backed with layers of wood, and fitted in a proper and mechanical manner into an actual structure, was also no ineffectual element in their success.

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* The sketches are copies from a photograph kindly furnished me by Colonel Gallwey, R. E.

"The naval designers having to provide, under the necessities by which they are bound in respect to the flotation, handiness, size, and other qualities of their ships, the greatest amount of protection, with a minimum of weight and thickness in the armour, have always worked on, very properly, as we think, with thicker and thicker solid plates. The Royal Engineers, designing our land fortifications, on the other hand, have always enforced the opposite view of economy of cost, and have professedly preferred to build up their armoured defenses by layer-upon-layer of 5-inch plates, disregarding the amount of diminished power of resistance, which such combinations have been considered theoretically to have, and hitherto practically have been proved to possess, in comparison with equivalent total thicknesses of solid iron. It is a matter of very great importance, however, to keep the burst of shells outside the wall of the ships' armoured side, and in attempting to test this layer-upon-layer system, for the sake of its economy of cost, in respect to its applicability to vessels of war, a certain modification was judiciously made in dividing the 14 inches thickness of iron into two layers only, and placing the thickest (8 inches) at the front, backing it with 9 inches of teak, and then placing the thinner layer (6 inches) next to this, and backing it again by 6 inches of wood. The object, therefore, of this trial, was to test not only the capability of resistance of the turret-armour of one of our most formidable iron-clads, but the respective powers of resistance of the two classes of armour—solid iron with solid wood backing, and layer upon layer of iron with intermediate wood backing.

"The first series of experiments laid down in the programme, issued under the authority of the director of artillery, (General Adye, C. B., R. A.,) was devoted to this subject. Two targets were erected. One (No. 34) having this structure in front, two plates superposed, each 14 inches thick and 3 feet 6 inches wide, the upper one rolled by Sir John Brown & Co., of Sheffield, and curved by dogs catching the end of the plate, while hot, in passing through the rolls; and the lower by Messrs. Cammells, of Sheffield, and curved, while hot, in the manner originally introduced by this eminent firm, by hydraulic pressure; next, a backing of 9-inch timber, disposed vertically; then a layer of 6-inch planks, disposed horizontally, with two angle-irons at about one-third of the structure respectively from the top and from the base; the whole supported by a double skin of ⅝-inch plate, strengthened by double angle-irons and deep vertical girders, with occasional bracket-pieces of ½-inch plate. At the top and the bottom the whole was bound together by plates of 1 inch thickness riveted to the edges of the front armour-plates. The other target (No. 35) was thus formed: two front iron plates, 8 inches thick, (upper one, by Brown's; lower one, by Cammell's;) backing of 9-inch timber, disposed vertically; two iron plates, (upper, Brown's; lower, Cammell's,) each 6 inches in thickness; layer of 6-inch planking horizontal, with two angle-irons as before riveted to the back skin, composed of two ⅝-inch plates; the whole supported and strengthened by double-angle iron girders, bracket-pieces, and top and bottom plates, as in No. 34. The targets were fixed in position at the rear by piles and struts of 12-inch timber. The gun brought against these structures was the 12-inch Woolwich muzzle-loading rifled 25-ton gun, placed at a distance of 200 yards, and firing Palliser large-cored shot, 600 pounds weight, and Palliser large capacity shells of 586 pounds, (empty,) and containing bursting charges of about 12 pounds. The gun was fired with 85-pound charges of pebble-powder."

In Appendix I will be found the detailed account of the firings, taken from the same source.

The "Engineering" Journal thus comments: "The deductions are that the 14-inch solid plate proved itself superior to the same amount of metal differently arranged, and, therefore, confirms the principle of construction as adopted in the turrets of the Devastation." (See Professional Papers, C. E., No. 21, pp. 114, 115.)

The following account of the experimental firings of July 5 is taken from "Engineering," (July 21:)

"The target is 48 feet in length by 9 feet in height, and represents two distinct systems of construction. In the one the face consists of an 8-inch armour plate, manufactured by Messrs. Cammell & Co., 6 inches of teak, and behind this a 5-inch armour-plate, by Messrs. John Brown & Co., backed by 6 inches more teak, with skin-plating 1½ inches thick in the rear The remaining portion of the target is built up upon the principle of the recent test targets, and has an 8-inch face-plate, backed by 18 inches of teak, supported by a ¾-inch iron skin, and stayed with iron ribs representing the framing of an ordinary iron-clad ship. The plates are all arranged so as to break joint with each other, the front plates in the compound portion of the target being 22 feet 6 inches and 25 feet 6 inches long, respectively, the rear plates averaging 15 feet in length. The firing was all made at 200 yards range, the 9-inch Woolwich muzzle-loading rifled 250-pounder gun being laid against the 8-inch or single portion, and the 11-inch Woolwich muzzle-loading rifled 500-pounder gun against the 13-inch, or compound portion of the target. The calibre of the latter gun—11-inch—is a novelty at Shoeburyness, although the gun itself is of the same weight as the old 12-inch 600-pounder.

"The 9-inch gun had the first innings, charged with 43 pounds of R. L. G. powder, a 9-inch small-cored Palliser 250-pound shot, with 1.5 ogival head, empty, and plugged in the rear, and laid against the 8-inch or A portion of the target. The shot struck the upper plate 6 feet from its proper right end, and 12 inches from its lower edge, making an indent of 10¼ inches mean diameter. The head of the shot remained in the hole, and gave a total penetration of 13½ inches, the rear portion of the target remaining intact. In the second round, from the same gun, with a large-cored Palliser empty shot, the projectile struck the same plate 9 feet 6 inches from the proper left end, and 1 foot 2 inches from the lower edge. An indent 9.3 inches in diameter was made, the head of the shot remaining in the hole, giving a total penetration of 2 feet. An examination of the rear of the target disclosed two broken ribs and a bulge, with some slight cracks in the skin. The third round consisted of the same powder-charge, and a Palliser shell carrying a 5-pound 8-ounce bursting-charge, which struck the lower plate 7 feet 9 inches from the proper right end, and 2 feet from the base of the target. A hole was cut clean through, the diameter at the front being 9½ inches, whilst in the rear the skin was broken away over an area of 18 inches by 15 inches, one rib and angle-iron being forced out and distorted. The fourth and last round with this gun was fired with the same powder-charge as before, and a 9-inch large-cored shot, having a 4-pound bursting-charge. It struck the target at the junction of the upper and lower plates, knocking a hole clean through to the rear, the skin being broken away, and one of the ribs being bent back for a length of nearly 3 feet.

"The 11-inch gun was next laid against the B, or compound portion of the target, the first round being fired with 85 pounds of pebble-powder, and a large-cored empty Palliser shot with shell-plug in rear. The upper plate of the target was struck 8 feet 6 inches from the proper right, and 1 foot 3 inches from the lower edge, complete penetration being effected. The mean diameter of the hole was 11¼ inches, and the plate was lifted bodily up and separated from the lower one, the separation between the plates being 1.2 inch at the proper right end, vanishing to *nil* at the other end. The damage to the rear was considerable, one rib being torn away for the entire height of the target and buckled 15 inches in the centre. The hole in the rear was 12 inches in diameter, and the outer skin was torn away over an area of 20 inches by 20 inches, a 3-inch armour-bolt being considerably bent. The head of the shot was found about 80 feet to the right of the target, having taken a course nearly at right angles with the line of fire, and grazing first at about 42 feet. The second round was fired with a similar charge to the last, the shot having a 6-pound bursting-charge. The projectile struck the upper plate 16 feet 6 inches from the proper left end and 2 feet from the lower edge. Like its immediate predecessor, it passed clean through the target, leaving a hole in front 11.2 inches mean diameter and buckling the plate 1 inch over its whole length, the rear one rib was broken through and another much damaged, whilst a third was torn away from the skin, twisted, and buckled 6 inches in the centre. A number of rivet-heads were cleared off and an opening was made in the backing 12 inches across, the skin being torn away over an area of about 2 square feet.

"In a previous series of experiments at Shoeburyness, made against the 14-inch solid-plated and the 8-inch with the 6-inch compound turret targets, with the 12-inch gun, that weapon failed in complete penetration. Now, however, it has gained the mastery with a reduction of only 1 inch of metal and 6 inches of timber. This victory appears to be due to the reduction of 1 inch in the calibre of the gun, which seems to give the requisite penetrative power, although the weight of the projectile is decreased. There is, of course, less work to be done by the shot in the present case in the way of displacement of metal, as the hole to be punched is 1 inch less in diameter than with the 12-inch 600-pounder shot. The character of the metal in the plates may be judged of by the fact that the shot-holes were as clean as they possibly could be, no cracks or fissures appearing, whilst the holes were but the veriest trifle larger than the projectiles which had made them. So with the shot; they were of splendid quality, and for this, credit is due to Colonel Milward, C. B., R. A., who has successfully solved the problem of the proper admixture of irons required in the production of a perfect chilled projectile. The results of these experiments have some bearing on the proposed enlargement of the calibre of the 35-ton gun from 11.6 inches, as at present, to 12 inches. Although they do not go to prove the desirability of such a step, it may yet be questioned, on the other hand, whether the retention of the present calibre will be of any use in rendering the gun serviceable. It should be borne in mind that the powder-charge of 120 pounds occupies a great length in the bore of the gun, and that a portion of every charge is blown out unconsumed—as, indeed, it is in some of the heavier guns at Shoeburyness. By enlarging the bore of the gun the length of the powder-charge becomes reduced, and, further, by igniting it in a central manner, as long since proposed by Sir Joseph Whitworth, its full theoretical power may probably be developed, especially if powder-pellets of slightly smaller diameter than those hitherto used, be tried. However this may be, the guns are certainly victors over the targets once more."

While I was present on the occasion referred to, two shots, from the 10-inch Woolwich rifled gun, throwing 400-pound cored Palliser projectiles, with 70 pounds of powder, were fired at the first-described portion of this target. The results were of sufficient interest to merit the insertion here of the detailed account taken from the Standard, September 27:

"Round 1. With Palliser large-cored shot, with a shell-plug in the base, enabling it to be used as a shell if required. The large Palliser projectiles requiring for their proper manufacture to have large cores, the shell-plug has been very properly added to utilise the shot for shell purposes. Weight of projectile, 396 pounds, empty. Shot struck the lower armour-plate of the target about the middle of its length, near to its upper edge, the centre of the shot-hole being 8 inches away, and a rim of 2 inches of iron left above it in the plate, perfect, without the slightest crack, although bulged out fully ¾ inch. Penetration such that the point of the shot protruded some 3 inches in the rear. The damage done at the back of the target was unusually severe, the skin-plates being very brittle, as if the iron had been burnt, or had been rolled too cold. The riveting also gave way in a very uncommon manner. The deep ribs on each side were split off nearly from top to bottom, being separated over a length of 8 feet from the skin, the total height of the target being 9 feet. These ribs were also split across; the skin was fractured into more or less rectangular masses for a distance some four feet above the shot-hole and for nearly three feet below it without the metal being driven up into a high cone, as is commonly the case. The target was set on fire by the shot, and the fire could not be put out by buckets before the following round was fired. A 3-inch common bolt had its nut broken off at the commencement of the screw-thread, and many rivets were started off from ribs beyond those adjoining the place of impact.

"Round 2. With same charge and nature of projectile, but this time the large-cored Palliser shot was filled with 4 pounds of powder as a bursting-charge; total weight of projectile, 400 pounds. Shot struck on the horizontal junction of the lower and upper armour-plates, the shot-hole being 6 inches into the upper one and 4 inches into the lower one. Radial deviation 2 feet high, 6 inches right. The shot-hole perfectly clean, with a good ripple, the surrounding metal of the plates being squeezed partially over the sunk heads of two English's bolts, one close above and the other about 3 inches below the orifice. Armour-plates separated about ½ inch. Penetration clean through, the shell bursting within the target, and the splinters going beyond to the rear. At the back of the target the rib on the left of the hole was torn away nearly its whole length, and split across; the one on the right also had its rivets shorn and was bent aside.

"The penetration of this target is, as we have said, undoubtedly remarkable; the armour-plates, rolled by Cammells, have all the qualities to which excellence is assigned, but the target was not erected by that firm, nor were the skin-plates and the ribs rolled by them. The compound structure of thick laminations of iron and wood we have always regarded as a weakening mode. The teak-timber in the backing does not appear to be quite as sound as it should be, and no doubt the giving way of the ribs and the seeming want of strength in the skin, are very serious deficiencies in the support afforded to the armour in this target. It seems to us a mistake to unite the work of several manufacturers in any structure instead of making one responsible for the whole. The target was again set on fire by this round; there was a ring of flames within the shot at each inward ripple of the armour-plating; the backing of a composite structure thus apparently being more liable to take fire than when there is one solid plate in front."

As concerns the work of construction of sea-coast defenses in England, the "Report" (Professional Papers, No. 21) leaves nothing for me to say except that the system therein described has since been rapidly advanced toward completion. The system itself is thus described in that Report:

"First. For points of peculiar character and very great importance, the artificial or otherwise contracted sites of which require the greatest possible concentration of guns, and which may be closely approached and enveloped by hostile fire—works of the character described as the 'Plymouth Breakwater Fort,' the characteristic being a continuous envelope of iron around that part of the work occupied by gun casemates. These works have generally but one tier of *casemate* guns, though, as we have seen, two tiers are to be given to the 'Horse Sand' and 'No Man's Land' forts. But the duplication of tiers is admitted to be objectionable, and is, therefore, we may assume, admitted for these two works only on account of the urgency of having more guns than can be placed in a single tier. Plate VI exhibits these works.

"For the roofs of these works, guns, if used at all, are to be placed in turrets. This arrangement is, indeed, almost a necessity, for though the height may be sufficient for 'barbette', or shield-protected arrangement, yet, the roof area is so contracted that guns thus mounted would be exposed to reverse fires, shells, &c., to a degree sufficient to render any efficient service, except at very long range, impracticable. Thus far, however, the plans for turrets have taken no practical shape, and the works are in course of completion as rapidly as possible without them.

"Second. Another class of sites more numerous than those just alluded to, scarcely less important, but not so liable to accumulated and enveloping hostile fire, are marginal positions on great rivers, navigable channels, or harbors. For these, when naturally contracted, as they very commonly are, or low, as is equally common, masonry works, with from one to two tiers of casemates, were the usual form which batteries assumed under the old system. For such sites the English have applied masonry casemates, with, however, the important modification that, in place of the masonry scarp pierced by an 'embrasure,' an iron shield closes the front of the casemate and protects the gun. We have already described the character of the shield with which these casemates are now in process of being supplied. Its power of resistance to such guns as can now be directed against it may be judged of best by referring to the results of firings against the experimental shield of March, 1870.

"Third. For the terre-plein or roofs of the above works, and for other low positions liable to close approach, it is common (*e. g.*, the upper battery of the Gilkicker, of which sketches are given; the Southsea Castle batteries, &c.,) to put a tier of guns between traverses and behind iron shields; or, where the exposure is somewhat less, behind earthen embrasures, (*e. g.*, the upper battery at Drake's Island.) As an alternative to these arrangements, the Moncrieff mounted gun is authoritatively mentioned. For example, it is stated by the committee of 1869 that the shields are to be dispensed with at the Southsea Castle batteries, and the Moncrieff carriage substituted; and similar statements occur frequently, both in the report of the committee and in the minutes of evidence.

"Fourth. For high batteries, say, of 100 feet and more elevation, batteries *en barbette, i. e.*, firing over the parapet and without embrasures, are used."

It is furthermore therein stated that only at a single work of the first category, viz, the Plymouth Breakwater Fort, had the iron-work been commenced; that the foundations and masonry substructure of the Horse Sand, No Man's Land, and Spit-Bank Forts were well advanced toward completion and readiness for the iron superstructure; that the works of the second category had been built, but were (at the time of our visit) yet without their iron shields.

The first-named work is now believed to be essentially completed according to the construction described, ("Report," p. 23.)

The Horse Sand and No Man's Land Forts, 2,000 yards distant from each other, rising from the water on the opposite sides of the main channel of entrance to Spithead, (See "Report," Pl. II,) are of paramount importance. The iron *frame-work* for the Horse-Sand superstructure had been completed and put together at the establishment of the Fairbairn Engineering Company, Manchester. I procured, through the kindness of Colonel Nugent, R. E., (acting deputy director of fortifications in the absence of Colonel Jervois,) permission to visit the structure, but was prevented from doing so by engagements. The following description, taken from the London Times, is deemed of sufficient importance to be inserted, as exhibiting one of the most interesting and recent statements of the condition of the art of the "fabrication of iron for defensive purposes and its uses in modern fortifications and works of coast defense."

"By the term frame-work the reader must understand the skeleton state and form of the forts, as distinguished from the armour with which they will be clothed hereafter, and the armament which they are intended to carry. One of these structures is quite complete, and the first thing to notice about it is its extraordinary size. It covers a circle, the diameter of which is 200 feet. The foundation prepared for it rises out of the sea to about 16 feet above high-water mark. From this platform the iron walls of the fort will ascend to a uniform height of 26 feet, and above this there will be a bomb-proof roof. When all is done, the vertical side, or wall, will present a blank face all round, varied by no features whatever, save the noses of the guns, except at the entrance port, where the gun will be omitted. The holes for the guns to peep through will be the only openings (with that exception), each perhaps 4 feet by 3 feet. All the rest of the wall—the whole exterior of the fort—will be dead armour-plate, with the roof to crown it. This will be the ultimate aspect of the work, but in its present condition we have to deal with a comparatively open-looking structure, entirely roofless, and *minus* all the armour-plating with which it will be enclosed.

"Until the plating is added, there will be seen only the huge upright piers, or supports; the floors, or decks, on which the guns will rest; and the vertical bars, somewhat stockade-like in appearance, to which the outer armour will be attached. The fort will carry 49 guns, arranged in two tiers, the upper containing 25 and the lower 24. Accordingly, the frame-work has rather the look of a skeleton building in two stories. It might be compared to the structural outlines of an amphitheatre, but the interior must be pictured entirely clear of stages and everything else. The circumference has a gallery all the way round, at a height about midway between the ground floor platform and the roof-beams. The floor and gallery represent the lower and upper stages or the guns. With these and their supports, and the armour to be added, the whole mass of iron work is exclusively concerned. It is an empty circus, the architecture of which is all at the circumference. The appropriation of the interior space of the fort is a matter with which the constructors of the frame-work are not concerned. The circular fabric which they have put together is divided into bays, in each story, by the massive vertical piers, 25 in number. These divisions, along two lines (upper and lower) of 600 feet—which is the length of the circumference—afford ample space for a gun in each; and the piers are so shaped in their inner portion as to allow the free play of the gun on its swivel-pivot.

"As regards the details of the structure, the component parts to be noticed are mainly the three classes above mentioned—the decks, or floors, for the guns; the vertical piers, and the massive upright bars for the armour. To take the piers first, they are composed of wrought-iron plates three quarters of an inch thick. Their dimensions are about 13 feet 9 inches by 7 feet 6 inches, and 22 feet high. Their hollow insides will be filled with concrete. The upright supports for the armour—which we have compared to a stockade in their present appearance—are solid bars of wrought iron, some measuring 12 inches by 8 inches, and the others 12 inches by 5 inches. These immense upright bars are repeated all the way round the outer rim of the structural circle, in the spaces left between the piers, and they uniformly extend from top to bottom. These and the piers, therefore, with the armour to be added, constitute the wall of the fort. The next element for review is the composition of the two decks. Both the upper and lower will be formed of enormous wrought-iron beams, laid horizontally, the outer ends of which will be carried by the iron structure itself, and the inner ones by the buildings within the fort; the spaces between the beams will be covered in with half-inch wrought-iron arched plates, well riveted to the beams, and filled in with concrete flush to the actual gun-floor, which will be formed of timber-planking, carried by these wrought-iron beams. There are, also, three horizontal external rings, one flush with the masonry and the other two at the levels of each deck as described, which are composed of solid wrought-iron plates 3 inches, 2 inches, and 1½ inches thick, respectively, and form a most important element in the strength of the structure. All the materials are of the best and most costly description of armour-plate iron, and have been furnished by Messrs. Cammell & Co., of Sheffield. Many of these plates are 26 feet in length, and one of these alone would represent a cost of about 170 pounds sterling. Without inquiring the exact number of them in the whole of this stupendous array of iron-work, the example just given is enough to prepare one for the total estimate of the price, recollecting that the multitudinous ribs and bones of the fabric are knit together from floor to roof all along a circumference of 600 feet. The cost of the fabric alone of the two forts, one of which we are describing, is about £900,000, exclusive of the armament. The Horse Sand and No Man's Land forts correspond in all respects, except that the foundation for the latter has been rather the more costly of the two.

"Before turning to the foundations, however, something must be said of the general character of this iron-work. All the military officers and professional authorities who have inspected it concur in pronouncing it superior to anything of the kind erected heretofore. The Fairbairn Engineering Company, in order to meet the requirements of the government in this important undertaking, have incurred a large outlay in providing special machinery to facilitate the production of the two forts and works of similar magnitude. As may be supposed, a large space of ground has been entirely occupied by the erection of the first fort during the fourteen months it has been constructing. As soon as it is removed, the same ground will be occupied for a similar length of time with the second fort. A special workshop had to be fitted up for the work, and a great number of the best and newest of Whitworth's tools had to be provided, as much to insure the accuracy of the work and perfect adjustment of all its parts, as to expedite its progress as much as possible. With the latter object, for instance, multiple drills were provided of the newest design, costing £500 apiece, and each drilling thirty holes at a time—no superfluous speed, considering that the number of holes to be drilled, all in their exact places, is reckoned by millions. The edge of every plate throughout the structure is planed, every hole has been drilled, and the edges of the iron were afterward taken off by machinery to prevent the force of a shot shearing the fastenings. All the plates had to be planed to the true circle outside. Before the artificers' work could be entered upon, the planing and marshaling of this bewildering multitude of details required long and careful labor. This has been effectually carried out by the Fairbairn company's engineer, Mr. H. M. Harman, C. E., in accordance with the general design of the work received from its authors at the war office; and the precision with which everything was foreseen and calculated may be gathered from the fact that when the whole circle of iron plating came to be put together not a farthing of expense had to be incurred in correction, so perfect was the adjustment of every part. All this nicety and finish must seem the more remarkable to non-professional eyes, looking at the unwieldy character of the materials employed. So exceptional was the severity of a great part of the manual labor involved in the actual combination of parts that only the most powerful workmen were equal to the strain. As already indicated, these two iron sea-forts will be the very first of their kind that the world has seen. As regards the strength of their frame-work for resisting attack, it is to be noted that being in the strictest sense homogeneous throughout, it has the great advantage that whenever a shot strikes it, the force of impact is taken on the entire structure, and not upon an isolated point.

"The armour-plate casing round each fort will be formed of three thicknesses of 5-inch plates, having spaces of 5 inches between each filled in with Portland cement concrete; but opposite to each gun there will be 17 inches thickness of armour-plates and 10 inches of concrete, the whole secured to the upright bars and the piers. Annexed are particulars of the 49 guns of the fort:

"*Guns in lower tier.*—Twenty-four 12-inch guns, of 25 tons, throwing projectiles of 600 pounds, with a charge of 85 pounds of new pebble-powder. Initial velocity of shot about 1,300 feet per second, and total energy at muzzle 7,000-foot tons; at 800 yards, 6,000-foot tons. Palliser projectiles from this gun will, at 200 yards, pierce 14 inches of armour, and, at 1,000 yards, about 13 inches; at 2,000 yards, say, 12 inches.

"*Guns in upper tier.*—Twenty-five 10-inch 18-ton guns, throwing projectiles of 400 pounds, with charge of 70 pounds of pebble-powder. Initial velocity about 1,360 feet per second. Total energy at muzzle upwards of 5,000-foot tons; at 800 yards, 4,400-foot tons. Palliser projectiles will pierce 12½ inches of armour at 200 yards; 11½ inches at 1,000 yards, and 10½ inches at 2,000 yards.

"Preparations are also made for five 2-gun turrets on the top of the fort, if they should be found necessary hereafter. These turret-guns would be of at least 25 tons. To these particulars may be added a few relating to the armament of the two smaller forts. The Spitbank fort will be of one tier and bomb-proof. Its armament will be nine 25-ton guns (as before described), in an iron battery composed of a front made up of four thicknesses of at least 5-inch armour-plates, resting against an iron skeleton structure. Three of the guns look seaward, and six guns of less weight in granite casemates look toward Portsmouth Harbor and the land. The total cost of this work will be about £180,000. In the St. Helen's fort the battery will comprise a large central turret containing two of the heaviest guns and two 10-inch 18-ton guns (such as above described), mounted on turntables behind iron walls. The estimated cost of this fort is £120,000.

"The works generally have been designed and carried out under the able direction of Colonel W. P. Drummond Jervois, C. B., R. E., who was also secretary to the royal commission. The iron-work of the forts was designed by Lieutenant-Colonel Inglis, R. E., in which, as also in the control of the execution, he has been assisted by Lieutenant English, R. E. The whole of the iron-work of the two principal forts has been constructed and erected at the works of the Fairbairn Company, at Manchester, and will be re-erected by them at the sites of the forts, under the superintendence of the company's engineer.

"Immovable as it looks, indestructible as it is designed to be, the immense fabric they have completed is about to be taken to pieces for conveyance to the south coast. The trip will doubtless be accomplished with that wonderful ease and celerity with which the railway era has made us familiar. Engineers and traffic managers contemplate a feat of this kind with equanimity. The world in general accepts the performance much as if it were the transport of a toy palace from the dining-room to the nursery, remote as the work is from the thought of child's play. This skeleton fort is an affair of about 2,400 tons in weight, but far more impressive in its visible magnitude, and there seems something colossal in the bare idea of undoing the whole of it, and so packing it off 'per rail.'

"The foundation on No Man's Land shoal is, we believe, sufficiently advanced to receive the structure. The works, both there and on the Horse-Sand shoal, have proved very troublesome and costly operations, extending over many years. The sites ultimately selected for the four forts agree nearly with the recommendation of the royal commissioners of 1859, though one or two positions have had to be abandoned, owing to the difficulty of obtaining a secure foundation. For the Horse-Sand fort the foundation is laid on the shoal at a depth of 11 feet below low-water spring-tides. At the level of high-water spring-tides the masonry is 210 feet diameter. Up to a little above this level the entire base consists of massive concrete blocks, with granite and other stone-walling on the outside. Upward, to a level of about 16 feet above high water, an outside wall of granite and Portland stone of great thickness supports the magazines, shell-rooms, and other stores. Upon this structure will stand the two-tiered circular iron fort.

"Whether it be the one which has been described as finished or the one about to be begun is immaterial, since there is no difference in their design. The formations of No Man's Land fort and Spitbank fort present no feature very distinct from that of the Horse Sand. At Spit-Bank the external diameter of the masonry at high-water level is 151 feet. For the St. Helen's fort the foundations were made by sinking a ring, nearly circular and about 130 feet external diameter, of iron caissons through the shoal into the clay below, excavating the sand inside the ring and filling in concrete. The granite-faced structure above high-water level contains the magazines, shell-rooms, &c."

It is stated in the Report (p. 29) that the fabrication of shields for the works of the second category (masonry casemated), the introduction of which had been delayed through uncertainty as to the best manner of construction, had been undertaken and was in progress to the full extent of the capacity of the great rolling establishments to furnish plates; and that the plan of construction of the shield of March, 1870, was, in its main features, adhered to.

As the result of the most elaborate and extensive series of experiments protracted through a period of nearly ten years—of, indeed, the *only* consecutive and logically connected series extended to its final term, and, as a thus *adopted* construction now being energetically applied to the final completion of the system of coast defense of the greatest maritime nation of the world—the shield deserves our especial attention. Hence, I introduce here, supplementary to the account given in the Report, extracts from the official report of Colonel Inglis, R. E. (Prof. Papers, R. E., vol. XIX:)

"The shield was made at the Atlas Works, Sheffield, under the inspection of the officers of the fortification branch. It was completed at the works in about thirteen weeks from the date of order to commence. The contract for it required that the materials and workmanship should answer the conditions of the specification for the iron-work of Fort Cunningham, Bermuda, which was then in hand.

"Under these conditions the piece cut out of each armour-plate to form the port was subjected to the established proof at Shoeburyness.

"For this proof, each piece is fitted with trunnions set in its longer edges, near one end, and these trunnions are held in holes made in two massive swinging iron bars suspended from overhead. Thus, when the plate is struck it is free to turn both on its own axis, and also to revolve or swing in the suspension bars. This method of holding the plates was adopted as entailing less cost for maintenance than other plans.

"The proof is carried out by firing a Palliser shot from the 7-inch muzzle-loading rifled gun at 30 yards with a 9-pound charge. A good 5-inch plate will stop this shot, and if very good it will show only a slight star crack and bulge in rear. An indifferent plate will let the shot through, and have a large piece taken off the back. A bad plate will let the shot pass easily through, and perhaps crack a good deal, or even break in pieces. There are other appearances which weigh in assigning figures of merit to plates, and which are brought clearly to observation in this proof.

"The plates of this shield gave very good results at proof, and were all three classed A 1; A being the highest of three classes, each of which has three grades.

"Samples of the thinner plates and angle-irons were tested in a test-machine. The former broke with strains varying from 21.2 to 24 tons per square inch of sectional area in samples taken lengthways in the plates, and from 15.07 to 18.3 tons in cross-samples. The reduction of area of cross-section of the samples taken lengthways, amounted to 13.5 and 19 per cent. upon the original section, and to 1.25 and 9 per cent. in cross-samples.

"The angle-iron broke with 20.6 and 25 tons per square inch, and a reduction of about 27 per cent.

"The armour-bolt iron was tested under falling weights, and broke with seven blows from a ton monkey falling 30 feet, the sectional area at point of fracture being reduced 50 per cent.

"The rivet-iron was of special make, and broke with a reduction of area of 52 per cent. under a tensile strain of 24.81 tons.

"The operation of setting up the shield at Shoeburyness occupied about seven weeks in the middle of the winter.

"The casing was sent in one piece, riveted together complete, except that the top plate of all and the top plate forming the sill of the opening for the port were only temporarily secured.

"The two inner armour-plates were first fitted to the casing, and the bolts to hold them on were carefully set in their places. The piers and upper parts of the casing were then filled with iron concrete, after which the armour-plates were removed, the top plate of the casing riveted on, and the casing, with the inner set of armour-bolts standing out to the front, was then ready to be moved into position. This was done by means of hanging it on a trolly by means of the opening left in it for the port. The trolly travelled on beams supported at their ends, running at the proper level, from front to rear, through the opening in the masonry structure. As the casing was the full size of the opening, and now weighed about 20 tons, it would not have been easy to get it into position in any other way.

"The three rear holding-down bolts were next inserted and nutted under the lower bed-plate, which had been built in the foundations of the masonry structure. The lower part of the casing under the port opening was then filled with iron concrete, and the plate forming the top of this part was slid in from the front and secured by tap-screws to the angle-irons.

"After this the inner armour-plate was run in to its position much in the same way as the casing was, only as the opening in the armour-plate was more contracted, it rode on a small traveller, temporarily constructed, and running on armour-bolts for rollers. Some considerable care in adjusting the plate was necessary to make its bolt-holes fit the bolts already fixed in the casing as above described. The four front double holding-down bolts were then fixed and nutted under the lower bed-plate, after which the concrete bed on which the shield was to stand was filled in.

"The next operation was that of placing the port-frame and getting in the iron concrete which was to occupy the space between the second and inner armour-plates. For the latter purpose an apparatus consisting of a boiler plate-skin, stiffened with angle-irons, was used. This was made the full width of the shield, but less than it in height by about 5 inches, and the top of it was made in the form of a flat table standing out to the front. In vertical section it was, therefore, of this shape ˥. This skin was fitted on the armour-bolts and held on by them at a distance of 5 inches from the face of the inner armour-plate already in position. The iron concrete was then poured in over the top of the boiler plate-skin. When cool the skin was removed, and the iron concrete with the port-frame was left standing against the face of the inner armour-plate.

"The second armour-plate, with its set of bolts standing out to the front, was next run in and nutted on to the inner set of bolts. The port frame and concrete belonging to the interval between the front and second armour-plates were got in as before, and the front armour-plate after them. The small spaces between the edges of the armour-plates and ends and top of the casing and the masonry, were wedged in with pieces of iron, and the shield was ready to be shot at.

"The first trial took place on the 2d March, 1870, under the superintendence of a special committee appointed for the purpose. The guns employed in the trial were as follows:

12-inch muzzle-loading rifled gun of	25 tons.
10-inch muzzle-loading rifled gun of	18 tons.
9-inch Whitworth muzzle-loading rifled gun of	14½ tons.

"The battery was placed at 200 yards from the shield.

"A programme was prepared, having for its object a thorough trial of the shield with the largest gun. This was so far carried out, as will be seen from Table I, that the first four rounds were fired from the 25-ton gun with full battering charges.

* * * * * * *

"At the end of the first day's firing the committee expressed their opinion 'that the shield had exhibited a very considerable amount of resistance, and that it appeared, in nearly every respect, to be fully adapted to meet the requirements for which it was designed.' They said also that it had been 'subjected to a fire far more severe than it would probably have to endure under the conditions of actual warfare, both as regards shortness of range and number of hits; it nevertheless preserved its entirety, and the back or interior parts showed no signs of penetration or sensible bulging.' They spoke of the fastenings as having 'proved eminently successful,' but mentioned the weakness of the port frames, the employment of iron concrete between the armour-plates, and the driving back of the shield to the injury of the temporary granite floor laid behind it, as points of exception to the generally satisfactory character of the shield. These matters will be noticed further on.

"It should be observed that at this stage the original 5-inch intervals between the armour-plates had increased to 8 inches between the front and second plates, and nearly 6 inches between the second and third.

"In the nine effective rounds which had been fired up to this time, the shield had received blows equivalent, in the aggregate, to about 43,000 foot-tons.

"Although the general efficiency of the shield had thus been established, it was afterwards thought desirable to subject it to further battering, principally for the sake of determining matters of detail for guidance in future constructions.

"For this purpose two rounds were first fired from the 12-inch gun at an inclination of 60° to the shield, or 30° from the direction perpendicular to its face. This practice took place on the 1st July, 1870.

"This gun was placed at 30 yards from the shield, but the charges were made equivalent to full battering charges at 200 yards.

* * * * * * *

"As sufficient information had now been gained with regard to the general structure of the shield, and nothing more could be learned in regard to detail, without an excessive expenditure of ammunition, the practice was discontinued.

"The shield had now received 17 blows, with an average energy equivalent to about 5,321 foot-tons per blow, giving an aggregate of upwards of 90,000 foot-tons, or more than 1,000 foot-tons per foot superficial of shield front, after deducting the space occupied by the port. This, it need scarcely be said, is far in excess of the battering that any previous shield had received at Shoeburyness.

"With regard to the three points named by the committee, as mentioned above, in which the shield was thought to be defective, the following observations may be made:

"First, as regards the port-frames. As before explained, these both gave way in parts close to the angles, and this, notwithstanding that the principle of construction adopted had been experimentally tested under heavy blows from a falling weight without showing that point of weakness. From their failure sufficient experience was gained to correct the defect, and in two subsequent trials (12th July and 30th August, 1870), with pieces of port-frames introduced between armour-plates, and strained by 600-pounder shot (rounds 1766 and 1767) planted close to them, ample strength has been secured.

"As these trials were only to decide points of detail, they will not be further noticed in this paper.

"Before leaving this part of the subject it may be observed that whatever material may be used as filling between the armour-plates, there will be the same necessity for strong port-frames. This opinion is strengthened by the result of a trial made 16th September, 1870, with a target composed of two armour-plates, with 6 inches of oak between them. The oak was put together with iron dowels. A 600-pounder shot was fired at it (round 853), when the oak was driven out with great force, breaking, in doing so, a strong bridge-rail 3½ inches deep; several dowels were broken. The splinters of wood would have been very destructive.

"Next, as to the use of iron concrete being, in the opinion of the committee, objectionable as filling between the armour-plates. In the first place, too little regard seems to have been paid to the advantage gained by the great weight of this material. As used in this shield the concrete was about half the weight of an equal bulk of cast iron, and, of course, this great weight contributed, in an important degree, to the general stability of the shield. This concrete is also of a consistency which is favorable to the even bedding of the armour-plates over their whole back surface when struck by shot. This was particularly noticeable in the present trial, in the absence of cracks in the armour-plates after the first few rounds.

" But, on the other hand, it is a costly and troublesome material to use, and there would be some difficulty in getting, at reasonable rates, sufficient cast-iron borings to work with it upon a large scale.

" If it should squeeze out under shot-blows near the port, no doubt it may be very dangerous to the gun-detachment; but it is not admitted that this need occur. By the proper use of other material, such as wood or rope, in the parts immediately around the port-frame, there is every reason to believe that the escape of the iron concrete could be prevented, even if the intervals between the armour-plates should increase as much as they did in this trial. But the increase from 5 inches to 8 inches, that took place in the interval behind the front armour-plate in this instance, after blows equivalent to some 40,000 or 50,000 foot-tons, may be regarded as altogether exceptional and excessive, and, in practice, not half that increase would ever occur.

"The committee also noticed the softening of the iron concrete when heated by the entrance of a shot or shell, and its tendency, in that condition, to escape through the shot-holes made in previous rounds; but on this it may be observed that in practice a shield will scarcely receive several rounds from such guns as those at Shoeburyness, planted close together, and even if the concrete does run out in parts, the resistance of the shield is not impaired to a very serious extent, as will be shown by an experiment noticed later in this paper.* Besides, the concrete soon sets again as hard as ever.

"However, considering all things, it may be wise to abandon this particular concrete for the filling between the armour-plates, and even to give it up for the casing also, if there should be difficulty in procuring borings on a large scale at low rates.

"As regards a substitute for the iron concrete, either brick-work in asphalte, or Portland cement concrete, will, judging from the experiment of 15th January, 1869, p. 265, vol. xviii, answer very well and probably it will be well to use wood immediately about the port-frames."

I have, in the above, omitted the details concerning the effects of each shot; for which I must refer to the volume cited.

The accompanying diagrams showing shot-penetrations in the practice of the 2d March and 5th July 1870, (from same source), more accurate than that given in the Report (Pl. I, Fig. I), are interesting as showing in the section and plan the actual penetration of the several shot and the practical invulnerability of the shield under tests applied.

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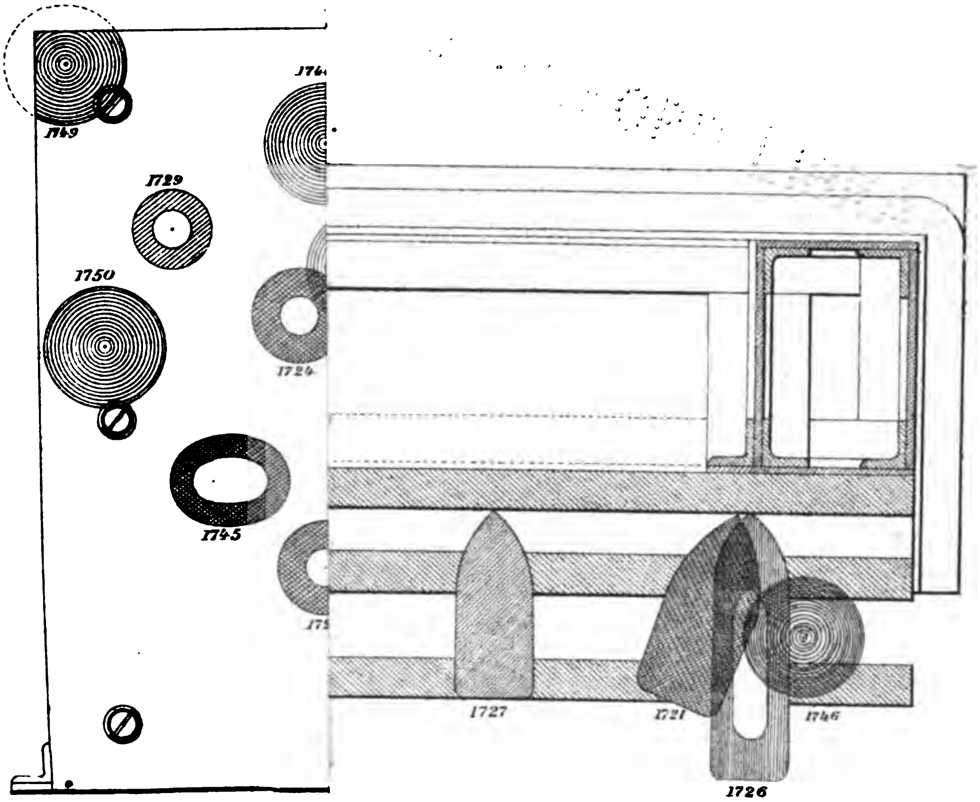
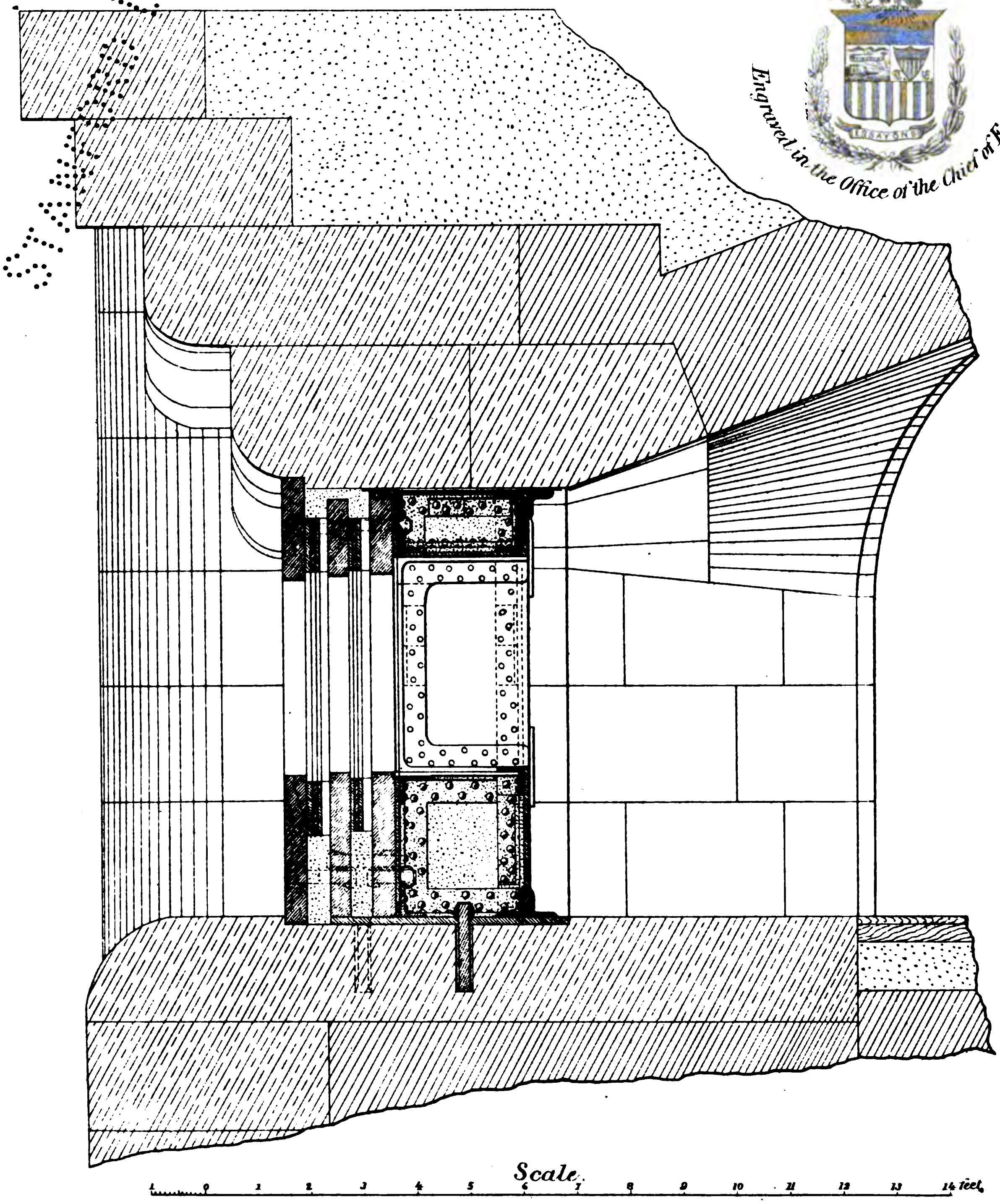
* "It may fairly be inferred that the penetration of a chilled shot into a plate-upon-plate target, with vacant intervals, will not be greater than when the intervals are filled with concrete, or other comparatively hard substance; but it does not follow that a target with air spaces would resist a battering so well as the other, for there is strong reason to believe that, without some filling between them, the armour-plates would crack much more, and give way under repeated blows by that means, without developing a fair amount of general resistance in the structure." (Reference is made to experiments on 'target composed of three 5-inch plates with vacant spaces between." *Vide* Prof. Papers, vol. xix, p. 106.)



PLAN.

12 IN SHELL *hatched thus*	◉
12 IN SHOT	●
10 IN SHELL	◉
10 IN SHOT	●
9 IN WHITWORTH SHELL	⬢
15 IN SHOT	◎

Engraved in the Office of the Chief of Engineers.



Engraved in the Office of the Chief of Engineers.

The sketch herewith will show that the shield and shield-frame together occupy the entire depth (about 5½ feet) of the opening in the front of the casemate; hence, these lateral masonry surfaces can throw off no splinters. Further, that no bolt passes through and through, and that no bolt-head is seen in the rear of the shield, the plates of which are each a single piece.

Without attempting to enter here into discussion of the merits or demerits of a design which may have had some of its features imposed upon it by the necessity of adapting it to arrangements made before the matter was illuminated by subsequent investigations and now fixed beyond alteration, I yet venture to assert that this shield is the best *existing model we have;* that it is probably the least costly, and that, for situations in which it can be considered admissible to expose masonry at all, it may be accepted as adaptable.

I have seen the announcement that the important work at Garrison Point, Sheerness (Report, p. 28), had received about half its required number of shields, and presume that at other important works there were, then, equal or even greater proportions supplied. Doubtless, at the present moment (April, 1872), this work is nearly accomplished.

The cost of the shield and frame is stated to be £1,400. Delivered and set up in this country the cost would be £2,000. If manufactured in this country the cost might, I suppose, be estimated at $15,000.

I have little to add concerning heavy artillery. Much additional experience as has been had in England with the 35-ton and other of the heavier calibres, which, while they leave, or rather, perhaps I should say, excite, some doubt as to whether the problems as to the suitable quality of powder—the relations of calibre, pitch of rifling—length of projectile, and bore—have yet received determinations at all reliable, on the whole, confirm confidence in the method of construction.

In mounting and handling modern heavy guns in casemates the English engineers and artillerists bestowed much study and attained results worthy of our attention.

A drawing with description (see Appendix II) of the "hydraulic buffer for checking the recoil of guns," now adopted, has been kindly furnished me by General Adye, Director of Artillery and Stores, who informed me that it had "been found to act most satisfactorily and is adopted in our service for all heavy guns on land-defenses."

A reference to the drawings of English carriages (see p. 99, Prof. Papers C. E., U. S. A., No. 21) will show that the English chassis is shorter than ours, and hence that the recoil is successfully taken up in narrower limits.

It is in place here to remark that in casemates, and in barbette batteries, the guns are trained by the "racers" *without a pintle centre*, except where, in the last-named batteries, an extensive sector of fire is needed, when a different arrangement of rails is made and a centre pintle is resorted to. The traversing is effected by gearing, which operates upon the rear trucks.

No considerable progress appeared to have been made in the actual introduction of the Moncrieff-carriage to the works in which it has been designed to use it. The inventor has modified his design, doing away with the *top* carriage and inserting the trunnions of the gun into the rocker itself; a very ingenious arrangement being adapted for preserving the parallelism of the gun.

This new carriage for a 7-inch (6½ ton) gun was experimented upon in my presence, and seemed to work admirably. A carriage for the 12-ton gun (9-inch) had been made, but had been returned to the machine-shops for some further modifications. The inventor expressed to me entire confidence of making it applicable to the heaviest calibres.

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APPENDIX I.

ACCOUNT OF FIRINGS AT EXPERIMENTAL TARGETS DESCRIBED ON PAGE 9.

ROUND I.—Against No. 34 target, solid plate (14 inches), with 600-pounder shot. Struck upper armour-plate (Brown's) 6 feet from proper right end, and 2 feet 2 inches from the top to the centre of the indent. Diameter of shot-hole, 13 inches by 12.7 inches; penetration, 13.95 inches; ripple clean; no starring or fissuring of plate whatever; mould of shot-head perfect; shot-head rebounded to the front 6 feet; top armour-plate set back by the blow over a length of 9 feet, and to the extent of 1.1 inches at centre, the ends of the plate being brought forward slightly, and projecting at the proper right end ¼ inch, at the proper left end ½ inch. At the rear of the target no practical damage whatever; iron skin perfect; no visible bulging of girders; 10 rivet-heads and 34 small tapped screw-bolts sheered, but thrown off with too little force to have wounded any one. Three of the washers of the large through-bolts more or less smashed. Target altogether slightly driven back.

ROUND II.—Against No. 35 target, 8 and 6-inch layers of armour, with 600-pounder shot. Struck on the junction of upper (Brown's) and lower (Cammells') face-plates 5 feet 6 inches from proper left end, and 3 feet 5 inches from top to centre of indent. Joint opened all along from ¼ inch at end to 1¼ inches in the middle; neither plate starred nor fissured; no ripple on upper; fine ripple projecting 4 inches on lower plate. Diameter of shot-hole 13 inches by 14 inches; penetration not exactly ascertainable, the head of the shot remaining in the hole embedded in the 6-inch plate; distance from surface of face-plate to back of head of shot 19 inches; probable length of shot-head 8 inches. At the rear very slight and not at all serious damage; skin perfect. One large through-bolt head sheered at commencement of screw-thread; six rivets sheered, and some splinter thrown off from the large through-bolt washers, five of which were more or less smashed. Two of the ship-ribs bulged, one 1.5 inches, the other 0.5 inch. The top

1-inch covering plate knocked up in front over a length of 6 or 7 feet to the extent of 4 inches in centre. One of the timber fixing piles slightly indented at top.

ROUND III.—Against No. 34 target (solid plate), with 586-pound Palliser shell, loaded with 11 pounds 12 ounces powder. Struck lower plate (Cammell's) low, 2 feet 6 inches from proper left end, 17 inches from bottom to centre of indent. Shell exploded to the front, throwing down a pile of sand-bags and timbers filling the space (about 6 feet) between the two targets. Diameter of shot-hole, 12.5 inches by 13.3 inches; penetration, 10.6 inches. Head of shell rebounded to the front a short distance; mould of head in plate perfect. The head of a large through bolt close to shot-hole contorted, and projecting 1½ inches. A small fissure extended from the shot through the narrow intermediate portion of plate (about 4 inches), gaping at the bottom 1 inch. No practical damage to the back of target; skin perfect. Six washers of the large through-bolts more or less smashed; 14 rivet-heads sheered. The whole structure driven back on the piling, one pile being cut through close to the ground, and one partly broken and splintered to the height of 4 feet, the target springing forward again 4 inches clear.

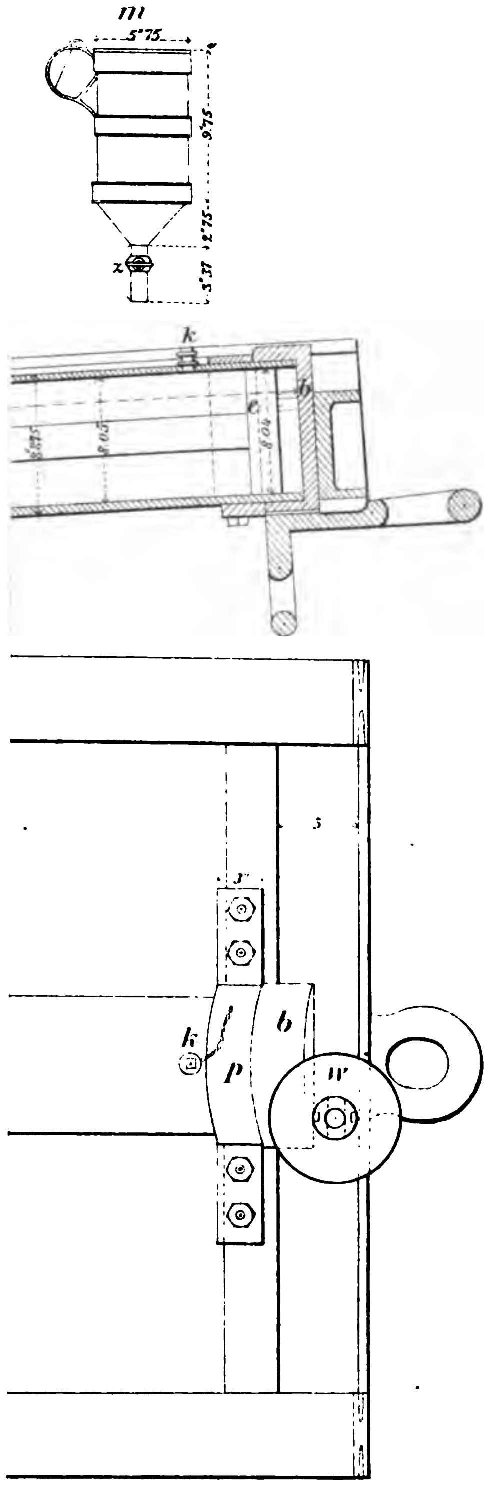
ROUND IV.—Against No. 35 target, with 586-pound Palliser shell, loaded with 12 pounds 8 ounces powder. Struck low on lower face-plate (Cammell's), 4 feet 3 inches from proper right end, and 9 inches from bottom to centre of indent. Lower portion of plate broken out 2 feet across, up to upper moiety of shot-hole. Face-plate bulged inwards some inches. The shell exploded in the ground below the target, blowing out a crater 4 feet deep, and through the 1-inch cill-plate. No practical damage at back of target; skin perfect. Four large through-bolt washers more or less smashed; three others bent; nine rivets sheered; wood-backing very slightly shaken. One firing-pile broken; another badly sprung.

The next practice was with 9-inch and 7-inch muzzle-loading rifled guns, and a 7-inch breech-loading rifled gun, mounted on Moncrieff's barbette carriages. After this practice from the 7-pounder muzzle-loading rifled gun, with charges of 8 ounces; then with war and life-saving rockets and parachute light-balls.

Then followed a short trial, with very good results, of the system of traversing heavy 10-inch and 9-inch guns by coupling the rear trucks and driving them along plain rails in the mode suggested in 1864 by Captain Beaumont, R. E. The guns fired yesterday from the models of casemates were fitted with pinion-gear by the Woolwich carriage department instead of the pitch-chain arrangement preferred by that officer, and which is certainly less liable to injury in working.

The practice which succeeded to this was against a section of a ship's deck, consisting of double ½-inch iron-plate, covered by 4½ inches of wood planking; the gun, 9-inch Woolwich muzzle-loading rifled, firing a Palliser shell of 244 pounds 8 ounces, loaded with 5 pounds 8 ounces bursting-charge, at a range of 100 yards. Gun-charge, 43 pounds R. L. G. powder. Inclination of target to line of fire, 14 degrees, viz., 12 degrees inclination in target, 2 degrees from gun. One round only was fired, the projectile striking the deck in line parallel with the iron beams, cutting a trench clean through 4 feet 6 inches long, and open 17 inches across in the wood and 9 inches in the iron plates. The shell exploded under the deck against one of the iron beams.

The experiments for the day terminated with ten rounds each, from, respectively, the new 9-pounder muzzle-loader rifled field-gun, with Shrapnel shell, the Armstrong 12-pounder breech-loader field-gun, with segment shell, and the new 16-pounder muzzle-loader rifled field-gun, with Shrapnel shell. The effects produced on the sets of targets representing columns of troops, at a range of 850 yards, were in all instances exceedingly destructive.



of wrought iron.

APPENDIX II.

HYDRAULIC BUFFER FOR CHECKING THE RECOIL OF GUNS.

(LAND SERVICE.)

The same buffer is adapted for use with 7-inch, 8-inch, 9-inch, 10-inch, 11-inch, and 12-inch guns, and consists of the following parts:

	No.
a, cylinder, lap-welded, wrought iron, bored to 8.05 inches diameter	1
b, cap, screwed, cast iron	1
c, flange, screwed, cast iron	1
d, cover, cast iron, with 7¾-inch bolts and nuts	1
e, piston, wrought iron, turned to 8.04 inches diameter	1
f, rod, piston, wrought iron, 2.375 inches diameter, screwed at each end	1
g, nut, piston-rod, collar	1
h, nut, piston-rod, connecting	1
i, gland, packing, gun-metal	1
k, plug, screw, filling hole	1
l, cock, metal, emptying	1

The above when put together constitute one article, "the buffer;" the following are the fittings, &c., connected with it, and of which only a proportion will be issued for several buffers:

	No.
m, measure, gallon, tin, graduated, with metal cock	1
n, spanner for plug and cock	1

The McMahon and general service knock-up wrenches are suitable for the nuts and glands.

The following are the platform fittings:

	No.
o, band holding down, front with 4 ⅞-inch bolts and nuts	1
p, band holding down, rear with 4 ⅞-inch bolts and nuts	1
q, plate, bearing, front (7 and 9-inch guns) with 2 ⅞-inch bolts	1
r, plate, angle, bearing, front, (10, 11, and 12-inch guns), with 4 ⅞-inch bolts	1
s, plate, bearing, rear, (10, 11, and 12-inch guns), with 4 ⅞-inch bolts	1
w, bands, leather, packing	2

The following are the carriage-fittings:

	No.
t, bracket, piston-rod, wrought iron, with 8 1-inch bolts	1
v, clips holding down with 2 ⅞-inch bolts	2

Four holes are drilled in the piston to allow of the passages of the oil; the size of these holes depends upon the nature of the gun. It is found that for the 12-inch 25-ton gun .9 inch is the proper diameter: for the 9-inch 12-ton gun, 1 inch diameter, and for the 7-inch 7-ton gun, 1.25 inch diameter; for other guns the holes will vary in a similar manner.

CONNECTING THE BUFFER TO THE PLATFORM.

Place the buffer, complete with its piston, rod, &c., on the front and rear supporting-plates, and observe that the cap *b* bears fairly against the rear transom; the screw plug-hole should be on the top, and especial care taken that the straight part of the front cover is parallel to the bottom of the carriage, to enable the latter to recoil free of it; when thus adjusted, the front and rear bands are secured. The leather packings *w* are placed between the bands and the cylinder to prevent the latter turning.

CONNECTING THE CARRIAGE TO THE BUFFER.

Move the carriage to the rear sufficiently to enable a man to get at the bracket on the bottom plate; remove the connecting-nut from the piston-rod, and draw the latter forward until its end projects through the hole in the bracket, observing that it is quite central in this hole, having the same amount of clearance all round it; screw on the connecting-nut, and when quite tight, take half a turn back to ensure a play of the bracket between the two nuts.

Before connecting to the carriage, the rod should be pushed in and out to see that it works freely, and that the packing-gland is not too tight.

FILLING THE CYLINDER.

Run the carriage up to the stops, take out the screw-plug and rest the gallon measure in the hole, turn off the cock and fill the measure with Rangoon oil to the gallon-mark, then turn the cock and allow the oil to flow into the cylinder; repeat the operation until the quantity required is run in. The greatest quantity of oil used should not exceed 12 gallons, which, with the carriage run out, will be 4½ inches deep at the filling-hole; this depth may be easily tested by a slip of wood; oil is withdrawn by means of the front cock, air being let into the cylinder at the same time by the removal of the rear plug.

REMARKS ON ITS USE.

It has been found in practice (water being used) that from 11 to 12 gallons is the proper quantity to give 5′ 6″ recoil with a 9-inch gun and 43-pound charge, using four 1-inch holes in the piston. Also, for each quart taken out the recoil is increased by about 1 inch. The difference in the length of recoil caused by a change from 43-pound to 30-pound charge was found to be only 7 inches, and the various recoils obtained with different slopes of platform, everything being kept the same, except the quantity of water, were:

4° (usual slope) 11 gallons of water	5′ ,, 1½″[*]
0° (level) 12½ gallons of water	5′ ,, 5½″
4° (downward slope) 12½ gallons of water	5′ ,, 9″

The rear buffers were, in the last case, compressed one inch.

Had oil been used the recoils would have been about one-tenth greater.

When not required for use the oil may be run out, the buffer removed from the platform and put away in store; but if required for occasional use in a battery, it may be left filled with its proper quantity of oil, and examined periodically, about once a month.

Water may be used in place of oil, in which case a little caustic alkali put in the water will prevent oxidation; the quantity required is about one-tenth less than the oil which it replaces. Field's non-freezing oil has been tried, and for very low temperatures it should be used in place of the Rangoon oil. Should a leakage occur at the packing-gland, and screwing up the latter be insufficient to stop it, the gland must be removed and fresh packing substituted for the old.

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[*] **When pellet powder is used, in place of R. L. G., the recoils will be about 8″ greater, it will, therefore, probably be necessary to make some alteration in the size or number of the holes.**

SEA SERVICE.

The foregoing remarks equally apply to the sea-service buffers as supplied to H. M. turret-ship "Prince Albert;" the greatest quantity of oil, however, should not exceed 11½ gallons, and the ordinary side-plate compressors, fitted with quick-pitched screws and levers, are used to control the gun when running up.

The buffer about to be adopted for boat-service in connection with the 12-pounder carriage and slide, is of smaller dimensions, viz., 4 inches internal diameter, the piston having 4 holes of ⅝-inch in diameter; it admits of a maximum recoil of 3′ 2½″. The proper quantities of oil, as laid down from practice by Captain Hood, of H. M. S. Excellent, are 13½ pints for the highest, and 12¼ pints for the lowest.

IRON SHIELD AND SUPPORTS FOR AN OPEN BATTERY.

Engraved in the Office of the Chief of Engineers.

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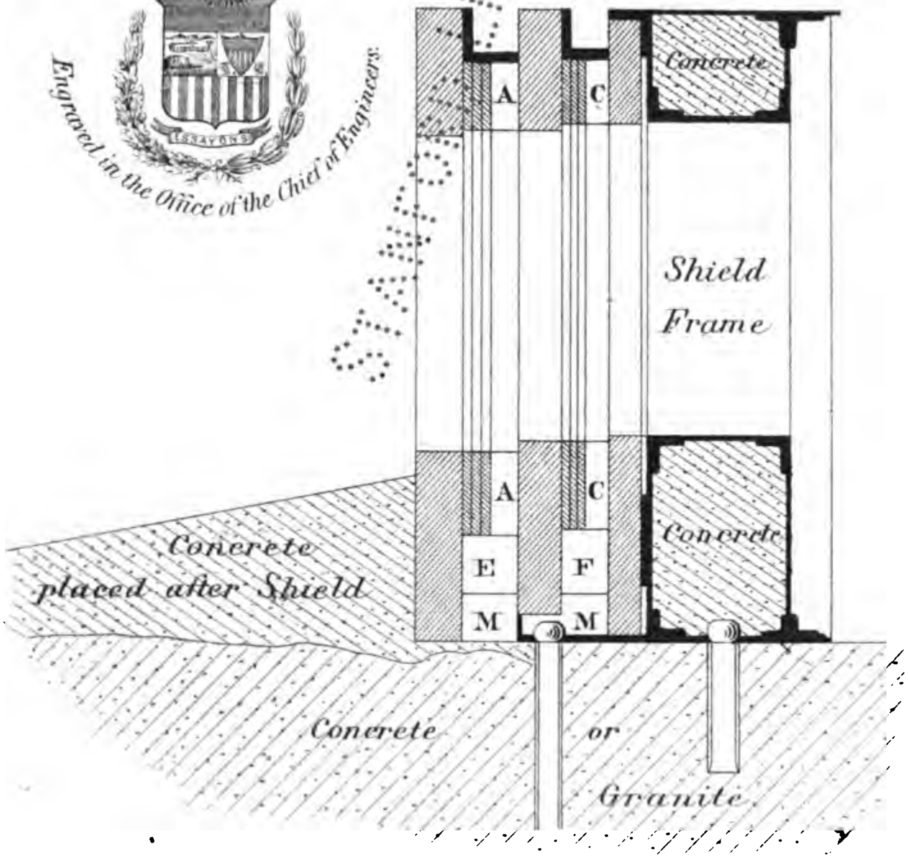

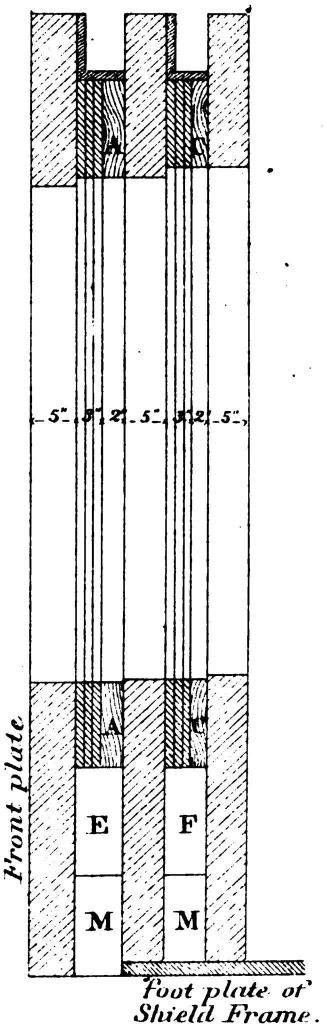

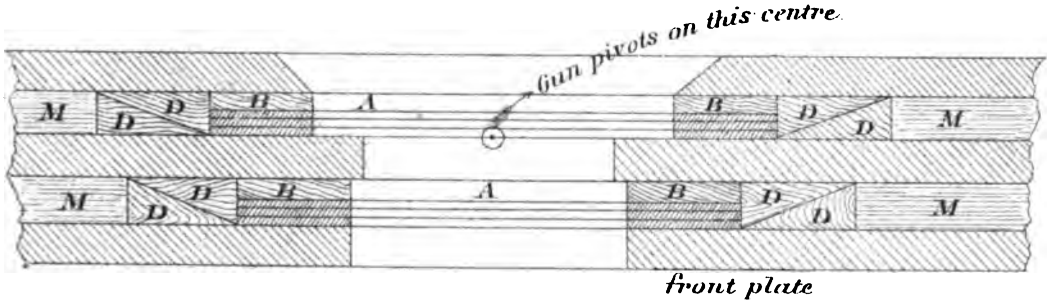

M M Filling of Brickwork in Asphalte.

SKETCHES OF WOOD FILLING.

Engraved in the Office of the Chief of Engineers.

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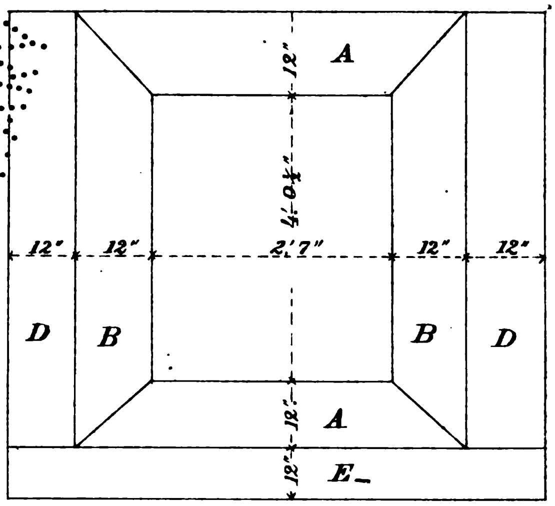

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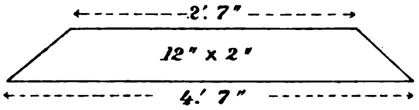

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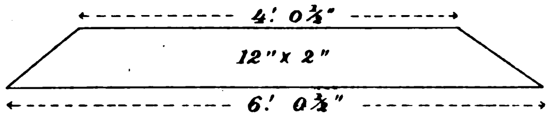

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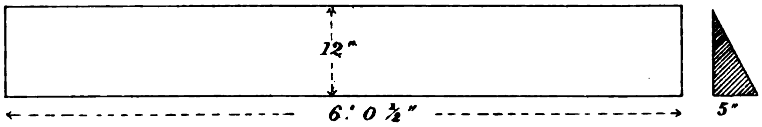

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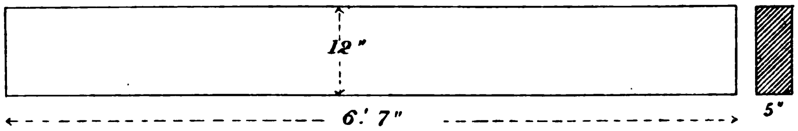

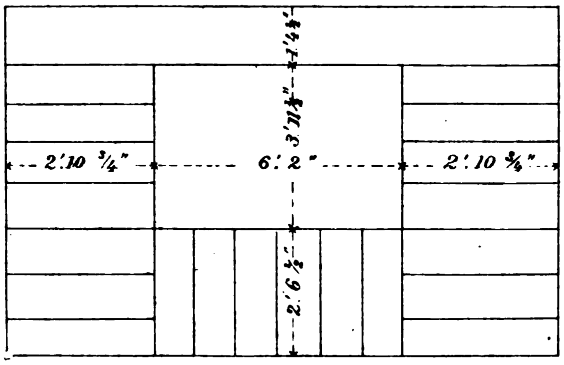

Wood between case and armor 1" thick.

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ADDENDUM.

OBSERVATIONS ON BATTERY AND SHIELD CONSTRUCTION AT HALIFAX, NOVA SCOTIA, AUGUST, 1872.

Referring to descriptions already given of the English shield, Professional Papers, No. 21, Corps of Engineers, United States Army, pp. 15–19, and the preceding supplement, pp. 22–25, I now communicate the following additional particulars derived from personal observation of the casemated and open batteries at Halifax, Nova Scotia.

The accompanying sketches (which, however, are for a shield intended for an *open* battery) will supply what is lacking in the pages referred to, for a full understanding of the details of the shield construction.

Doubtless for reasons set forth in paragraph 3, p. 28, brick-work laid in asphalte is adopted for the filling between the plates. For this purpose hard bricks of the highest specific gravity are preferred.

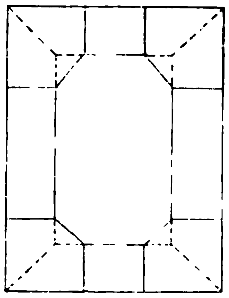
The port-frames are supported by the rectangular pieces of teak or oak, E, F, which, themselves, rest on the filling, M, M, and are also held in place by the large 3-inch armour-bolts which traverse them. The port-frames prevent the wooden frames E, F, D, D, which surround them, (and, filling the whole interval between the armour-plates, act as cushions,) from splintering into the port. Moreover, they are thought to possess a certain amount of elasticity from their being laminated. Made up of three thicknesses or rings of thin (one-inch) iron plates they do not, of course, fill the five-inch space between the armour-plates. The sketch shows that the remaining two inches is made up by the teak frames, B, B, by which the wooden cushion is extended to the very edges of the port. Since this sketch was made it has been decided to divide this thickness of wood (B, B) into two, putting one-inch before and one behind the port-frames; and this is the actual construction at Halifax.

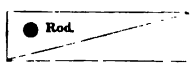
Outside the solid backing thus formed around the port is another frame of teak or oak, made up of pieces lettered D, E, F; E and F are rectangular in section, but D is composed of two wedge-shaped pieces, as shown in drawing.

As before observed, the sketches refer to shields designed for an open battery. The top in this case has no filling, and is finished off with a heavy angle-iron over the port frames and wooden pieces A, C. These angle-irons give a certain amount of rigidity to the top, which in granite casemates is obtained by letting one or more of the 5-inch plates engage with a 2-inch recess cut in the arch-stones.

The two inner plates rest on the foot-plate of the shield-frame, but the outer one does not. I presume this is unintentional, the frames being made before it was determined to put a third 5-inch plate on the shield. It would doubtless be better to place all the 5-inch plates on the foot-plate of the shield frame, which would have to extend further to the front for that purpose.

The assemblage of parts of the port-frames should be described. They consist, as has been before stated, of three thicknesses of one-inch iron. As it would be very expensive to cut each of these laminæ out of a single plate of metal, the middle one is made up of four pieces indicated by the dotted lines of sketch; the two external ones, each, of eight pieces, as represented by full lines. By means of the riveting, the three laminæ are united into one frame.



When the shields are intended for an open battery, the angle-irons between the armour-plates, at the top, just mentioned, are the sole means of confining the filling between the plates. To give greater efficacy to this restraint iron rods of about two-inches diameter are inserted, one on each side of the port-frames. These extend from the horizontal flanges of these angle-irons downward, longitudinally through the wedge-shaped pieces of teak, D,  thus, and through the foot or bed-plate.*

The experimental firings at Shoeburyness of March 2d and 3d, 1870, having shown that, secured by bolts alone through the bed-plate of the frame, the shield was "driven back" bodily, Colonel Inglis comments thereon as follows: (Prof. Papers, R. E., Vol. XIX, p. 102.)

"The only other point to notice is that of the shifting of the shield in the course of this trial. At the conclusion of the experiment the base of the shield was found to have been driven back some seven or eight inches, and

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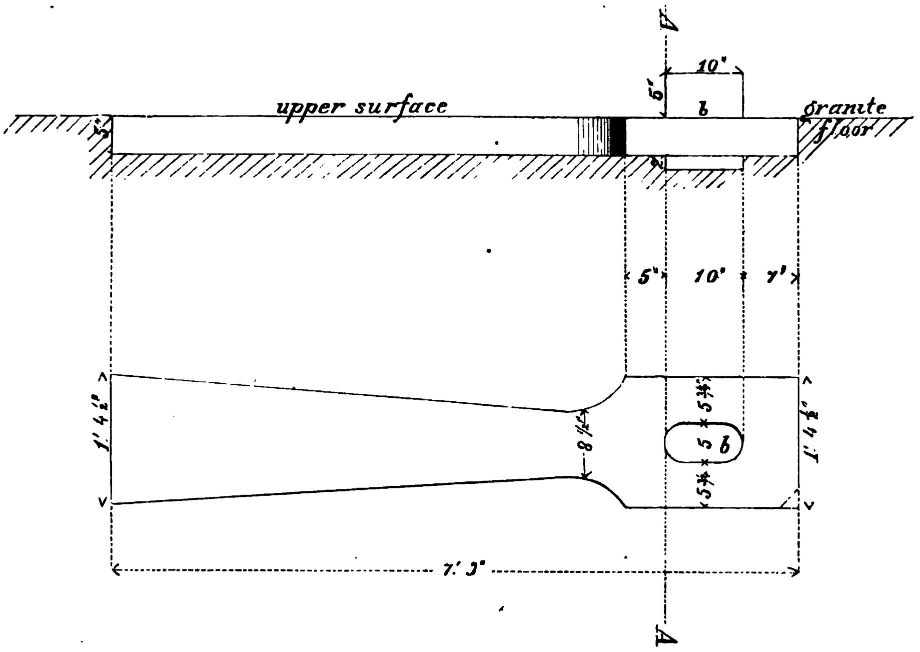
[*] As the bed-plate to the shield-frame does not extend beneath the interval between the external and middle armour plates, washers are provided at bottom to secure the lower ends of the two rods that traverse this interval.

to allow of this, the holding-down bolts had been bent to a considerable curve, and had also been elongated.

"On this it should be explained, that the granite blocks behind this shield were much lighter than those used in actual works, and were laid in a much more temporary manner than usual. In fact, in many respects they did not represent the floor of our casemated batteries at all. But still the derangement of the racers would be so serious a matter in action that it well deserves attention. In the first place, the ends of the base-plates under the piers should be very firmly secured, and the holding-down bolts should have large cross sectional area to resist the backward movements. It would be well perhaps to introduce some wood between the back edge of the base-plate and the granite floor, and even in some instances to introduce under the base-plate heavy iron cramps, let into the masonry and dovetailed in it, with stops to check the movement of the shield in rear. These cramps should be so placed and arranged as to relieve, as far as possible, the stones in which the racers are laid. With these precautions there will be no danger of the racers being displaced under a very considerable amount of battering."

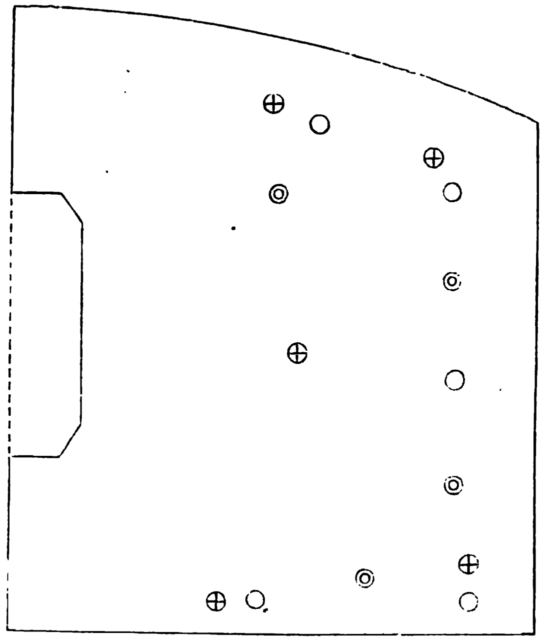
Cramps, such as are suggested above, have been introduced for the casemated shield at Halifax. The sketch herewith shows their form.



They are probably made from condemned or imperfect armour plates; hence their thickness of five inches. They are sunk into the granite casemate floor, and the toe or rear edge of the bed-plate of the shield-frame rests on the line A A (3′ 7½″ behind the pivot line) against the keys, *b b*. The two cramps are, centrally, 3′ 8½″ apart. The rear holding-down bolts are dispensed with.

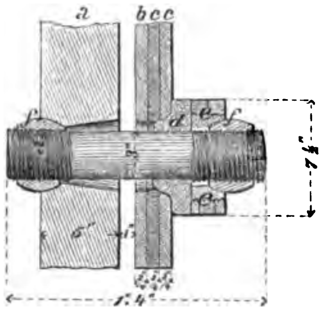
Open batteries afford no granite casemate floors in which to lay such cramps. At the Ives Point Battery a bed of concrete five feet deep, extending several feet in advance of the shield, and far enough back (say 18 or 20 feet) to afford a foundation for the granite blocks of the outer traverse rail, is laid. In this, under the shield and shield-frame, a block of granite of width exceeding their total width, and of thickness nearly equal to that of the concrete, forms the immediate foundation for the shield. The front holding-down bolts pass through the granite, through the concrete, and are secured in a washer or plate of iron under the concrete.

It has been elsewhere stated that there are no *through bolts* in the shields; each plate being bolted to *the next one only*, and the rear plate to the shield-frame. The disposition of the bolts is shown by the following sketch:



○ *Rear plate to frame*
◎ *Middle to rear plate.*
⊕ *Front to middle plate.*

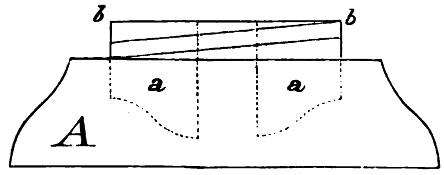
The bolts (see Prof. Papers, C. E., United States Army, No. 21, pp. 42, 43) are three inches in diameter with plus threads at each end. The spherical nuts have a radius of 4½ inches. But owing to the thinness of the iron of the shield-frame something more than such a nut is necessary. For this attachment a washer of large-bearing surface and some elasticity is deemed necessary, and a rather complex combination of *asphalte* and iron is employed. The sketch shows the arrangement.



a, inner armour plate.
b, skin of shield frame.
c,c, reinforcing plates.
d, asphalte washer.
e, spiral washer.
ff, spherical nuts.

The iron portion of the washer consists of a solid central ring bound round by a spiral band.

The *asphalte* (the *Seyssel*, in cakes) has just enough mineral tar added to give, under the action of heat, semi-fluidity to the mass which, while hot, is moulded in the cast-iron form A, by pouring and pressing it into the annular cavity *a*, *a*. Before it has hardened the spiral washer *b b* is applied and pressed upon it with force enough to secure a perfect fit, but not enough to force out the asphalte. When cool, the combined washer is removed from the mould.



To protect the gunners from smaller missiles the ports (or embrasures) are to be closed by mantlets hung from rods overhead; to bring the heavy projectiles to the muzzle of the gun a bar to support a travelling block is necessary. Brackets are provided on the shield-frame for sustaining these rods.

The process of inserting the shield into casemates of which the masonry has been entirely completed, is very similar to that described by Colonel Inglis, and quoted in the preceding pages, 23–25. The substitution of bricks laid in asphalte for iron concrete, as filling for the intervals between the armour-plates, will, of course, render the use of the auxiliary "skin" of boiler-iron there mentioned unnecessary.*

For filling the cavities of the shield-frame, ordinary concrete was used, composed of one part of cement, (Portland,) three parts of sand, four parts of broken stones, measured in bulk, dry. The frames are said to weigh seven tons empty, and twenty-two tons when filled.

In Plate III of Prof. Papers, C. E., United States Army, No. 21, the abutment masses between which the shields of the upper (open) battery are placed are assumed to be boxes of boiler-iron, filled with concrete. Such is not the case, however, in the shielded open batteries constructed at Halifax. These abutments are built of large blocks of granite. In either case there is a dangerous weakness at these points, but very much enhanced, I think, when, for the concrete-filled cases, granite is substituted. The *rationale* of this construction is placed in the assumption that the twelve feet of front cover provided by the shield is adequate to protect the gunners. The effects of flying fragments of the adjacent granite (or concrete) abutments, and of the projectile itself, do not seem to be taken into account.

The shielded *casemates* to which I allude are recent appendages to one of the fortifications in the harbor of Halifax. The original work is a polygon of five or six sides having masonry scarps with no re-entrant angles, covered by a counterscarp and glacis. The original battery was upon the ramparts of this work. The casemates I have mentioned have been recently inserted in the glacis on the side looking down the harbor.

These casemates have only the usual depth sufficient for the working of the gun, and free passage behind, probably 30 feet, measured from outside. The arches have a span of about 27 feet, and are from 55 to 60 feet apart, measured from axis to axis. The passage from casemate to casemate between the rear wall and the rear of the piers varies in length from 27 to 33 feet. In each of the spacious piers are, alternately, a shell-room and two expense powder-magazines; the former has an area of 8 or 10 by 12; the latter of 10 by 18.* Excepting these magazine areas the intervals between the casemates are filled by solid masonry. Externally all the masonry is entirely covered by earth except the arch and area over the shield opening, as shown by sketch.

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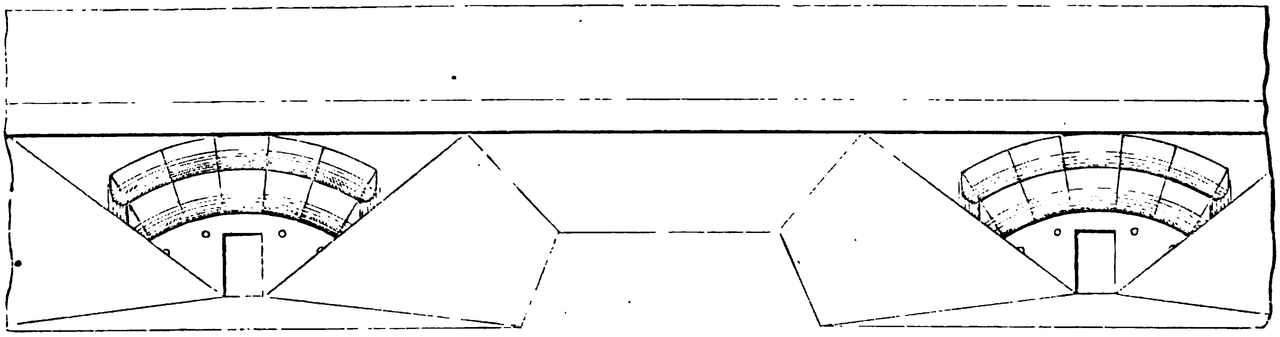
* The filling with bricks and asphalte is not unattended with difficulty, as the hot asphalte is very viscous, and cannot be placed with a trowel at all like mortar. Experience at Halifax has indicated the following process: Three or four courses of bricks are laid with a small quantity of hot asphalte as mortar, and then the free space between the brick and plate filled in with asphalte; and so on to the top. In order to "render," or apply the external coating of asphalte to, the brick work, by which a perfect bearing surface to the next armour plate is provided, temporary external casings of planks, embracing a small part of the height at a time, are resorted to.



A covered passage leads from these casemates through the ditch and scarp into the main work, the ramparts of which are arranged for heavy guns (10-inch Woolwich) as delineated p. 26, Prof. Papers C. E., United States Army, No. 21, except that they have not a central traversing pivot. The guns, 70 feet apart, are isolated by traverses 15 feet thick on top, and sloping down to gun platforms, and containing, alternately, shell-rooms and expense powder-magazines: the former are 8 by 15, the latter 8 by 12. The main magazine is centrally placed, and, with a T head, serves as a central parados.

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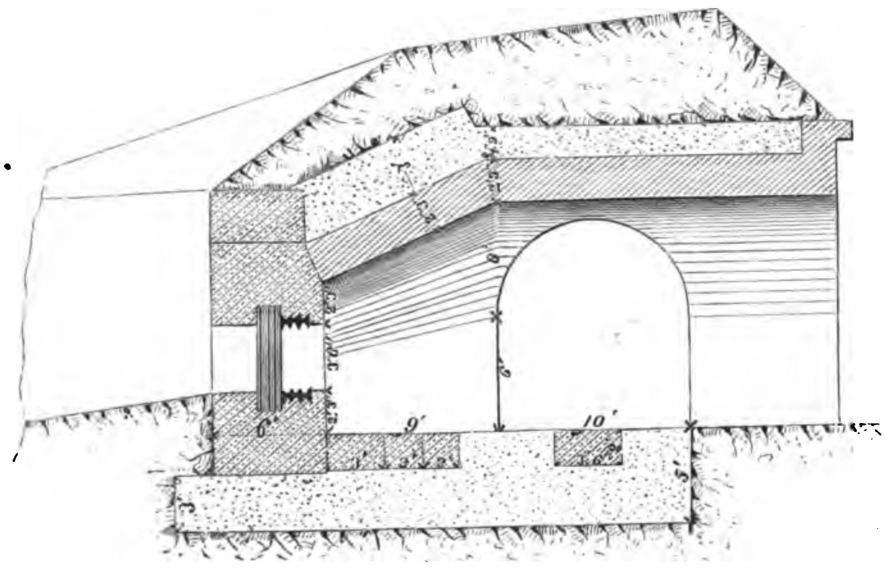
* It is presumed that this is the *joint* area.

At another work a system of casemates is inserted in the counterscarp, very much as described above; but the embrasures are revetted by railroad iron bars.

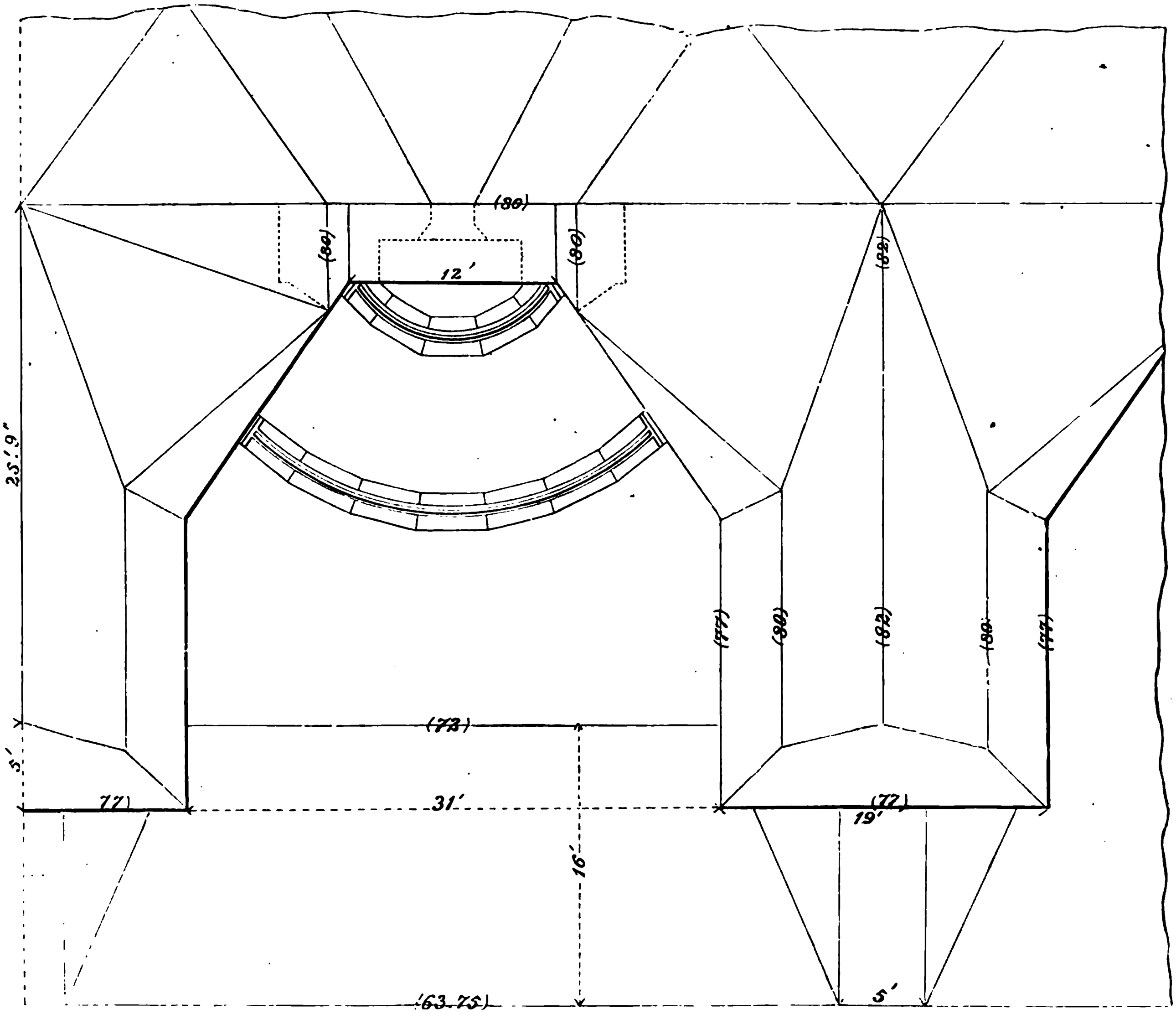
A section of the casemates is given in the following sketch:

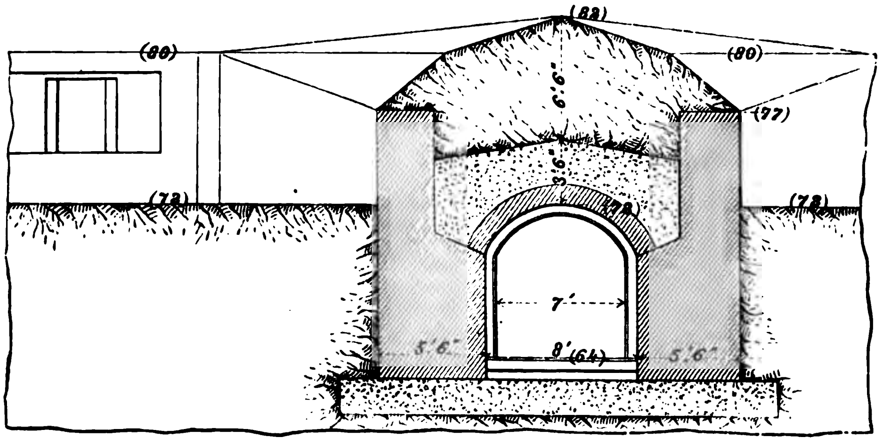


The span of the casemate at widest, is 20 feet; and there is 20 feet interval, measured in rear of pier from casemate to casemate. I think there were small magazines in these piers also.

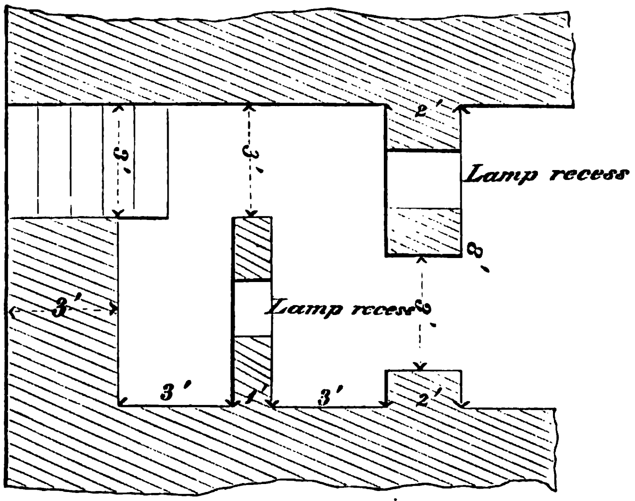
The opening in the masonry of the front wall is 7 feet wide, and 3½ feet high. Bars of railroad iron, as indicated in the above sketch, are inserted in this opening, to form the embrasure.

The following is a sketch showing a gun emplacement, with adjacent traverses for an open battery with iron shields. The manner of securing the shield to the platform has already been described:


(80)
(80)
(80)
12'
(82)
25'.9"
(77)
(80)
(82)
(80)
(77)
(72)
5'
77)
31'
(72)
19'
16'
(63.75)
5'


(88)
(80)
(80)
6'.6"
(77)
3'.6"
(72)
(78)
(72)
7'
5'.6"
8'(64)
5'.6"

There are, at other points, open-embrasure batteries very much like that already described and, indeed, such batteries differ little in the disposition of earth masses and in the character of the gun emplacements from open batteries protected by shields. At York Redoubt, for instance, the emplacement with adjacent traverse is about as follows: The guns are trained on grooved racers without central pivoting-bolt; the height from rail to embrasure-sole is 4′ 3″, about. The traverses are continued over the parapet as merlons, so limited by marginal slopes down to the sole of the embrasure as to allow the proper sectorial range of fire (60 or 70 degrees) to the gun. The parapets are usually thirty feet, or more, thick. The "genouillère" (4′ 3″ high, about) has a length of 12 or 14 feet, and the stone or brick wall reaches (this is true of *all* English batteries I have seen) *to the sole of the embrasure.* From extremities of the genouillère the revetment-walls flare back till the distance from traverse to traverse (30 feet in York redoubt) is attained, when they unite with the proper revetment wall of the traverse.* The thickness of these traverses between lateral sustaining walls is about 34 feet. So great a thickness is not universal. In batteries which had been constructed for lighter guns there are traverses with not over 18 feet thickness. In all cases, the magazine or shell-room which they contain has an ante-room with lamp-boxes in the walls. The sketch exhibits the arrangement of one at Cambridge Battery, but I do not know that this duplicate arrangement is universal:



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*The traverses almost invariably have on both sides a sustaining wall as high as the genouillère, which at the rear end becomes a profile wall.

The traverses in this (the York) redoubt are alternately fitted as shell-rooms and expense-powder magazines. The shell-room is entered by a porch* which covers the descent to the level of the floors; then there is an ante-chamber of five feet, to a shell-room 19 by 7. The interiors have laterally and overhead a brick furring 4 inches thick; above this ceiling is a brick arch 1 foot thick,† covered by 4 feet of concrete and 6 feet of earth. Besides these small expense-magazines in the traverses, there is *always* a main magazine. There is, also—and universally, I believe—a shell-filling room, quite detached from the magazine, with special and admirable arrangements for shell-filling.‡

In all cases in which the heaviest guns are used there is but a single one between adjacent traverses. Where the lighter guns have been used (*i. e.*, 7-inch Woolwich) they are generally coupled between the traverses. These are giving way to single guns of heavier calibre.

Where these open batteries do not form part of an enclosed work of some strength, they are usually enclosed at the gorge by a crenellated wall, and are supported by a tower§ or some enclosed assault-proof work. I noticed one important and isolated battery which, without sustaining works, had only a wooden stockade in rear; but the system of defense of the locality in question was evidently incomplete.

Concerning artillery, I have but few words to add to what has been said in Prof. Papers No. 21.

The batteries I have spoken of at Halifax are armed, or are being armed, with 9 or 10-inch (12-ton and 18-ton) Woolwich rifles. The carriages are essentially as delineated, Pl. XVIII, Prof. Papers No. 21, except that they are mounted when used for open, unshielded batteries, on higher trucks, and that the recoil is taken up by "hydraulic buffers," described in the "Appendix" II.

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*This porch is not observed (in this redoubt) in rear of the alternate traverses serving as powder-magazines.

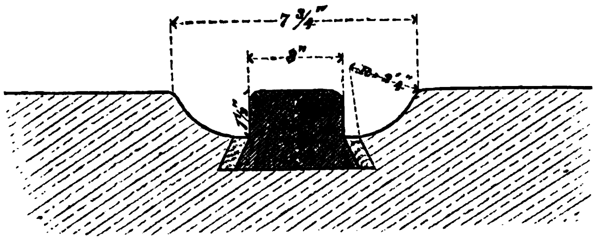
†The arched furring is turned *after* the brick arch. As the air-space is but 4 inches, the operation is one which requires ingenuity.

‡Concerning "expense magazines" and kindred subjects connected with the service of heavy guns in coast-defense batteries, I would refer to a paper in Vol. XIX of the Prof. Papers, R. E., headed "Details connected with the Service of Heavy Muzzle-loading Rifled Guns."

§Advantage has been taken of the old Martello Towers in several cases.

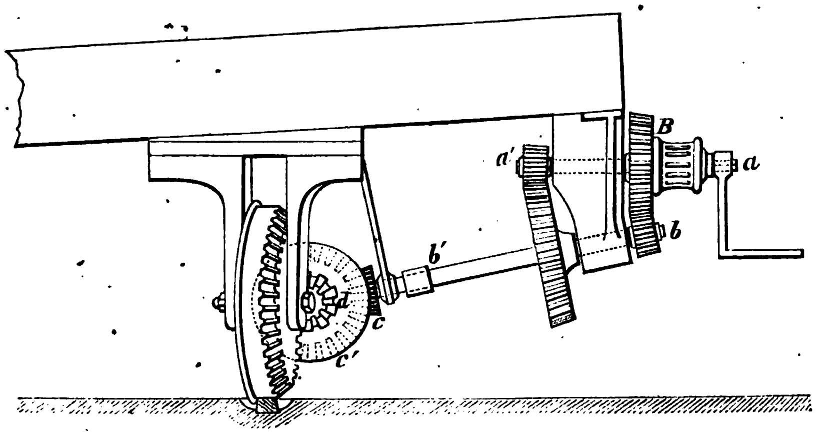
The use of the tongue and front pintle* seems to be entirely abandoned; the grooved racers alone resisting recoil, and governing the training motion.

The rails for the racers are attached to the granite polygonal platforms, as shown in sketch.



They are secured in the granite by packing with an alloy of three parts of lead to two of zinc.†

For training these guns, a gearing is attached, roughly sketched herewith.



The crank-shaft *a a'* passes loosely through the capstan *B*, driving, by its pinion, the spur-wheel on the shaft at *b b'*. At *b'* is a coupling-block by which the shaft is continued to a beveled pinion *c*, which drives two beveled spur-wheels, one on each side. One of these is seen at *c'*. On the shafts which bear these wheels, the beveled pinions *d* work into beveled spur-wheels in the rear of the hindmost trucks.

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* Pintles are in use for pivoting on centres either at the middle or the rear of carriage; for guns in salients when a large sector of fire is obtainable.

† In some cases the rail, two inches thick, was screwed to iron washers or nuts set at intervals in the granite, leaded in with the same composition.

Of course the capstan *B* is always driven, by the pinion at *b*, whether the racer-driving coupling is in gear or not. By throwing the latter out of gear, (by a lever suitably fixed,) and casting a training-rope around *B*, (iron rings in the traverse revetments are always provided as attachments for these ropes,) the capstan may be made serviceable in training the guns, *without* driving the trucks. When the coupling is in gear, the racer trucks are operated upon and the gun trained with great ease. The use of the capstan and rope is an alternative always available.

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